SPECIES RESPONSE TO OCEAN ACIDIFICATION IN THE FACE OF OTHER STRESSORS

Scientists estimate the ocean is 30% more acidic today than it was 300 years ago. This is due to increasing levels of atmospheric carbon dioxide (CO_2) emitted by humans that dissolves into the surface ocean waters, lowering the pH and increasing the acidity. Higher acidity water can reduce the ability of shell-forming organisms to build and maintain their shells, and can also affect the growth and behavior of fish.

While ocean acidification is expected to increase in the coming decades, it is not the only change that marine organisms will experience. Factors such as ocean warming and shifts in prey populations can create multiple stressors. Cumulative impacts are complex and not easy to predict, but scientists are developing a general understanding of how these factors will influence different species.

Crab

Although there are differences in the response of individual species, crabs are sensitive to higher acidity water. Juvenile crabs seem to be the most sensitive, although changes in acidity can affect any life stage.

Direct response to high CO_2 (more acidic) water:

- Decreased growth and increased mortality of juvenile red, blue, and golden king crab, and Tanner crab
- Altered embryo development in Tanner and red king crab
- Increased embryo and larval mortality in Tanner crab
- Reduced exoskeleton strength in Tanner and red and blue king crab
- Increased hemocyte (white blood cell) mortality in Tanner crabs

Potential indirect effects of high CO_2 (more acidic) water:

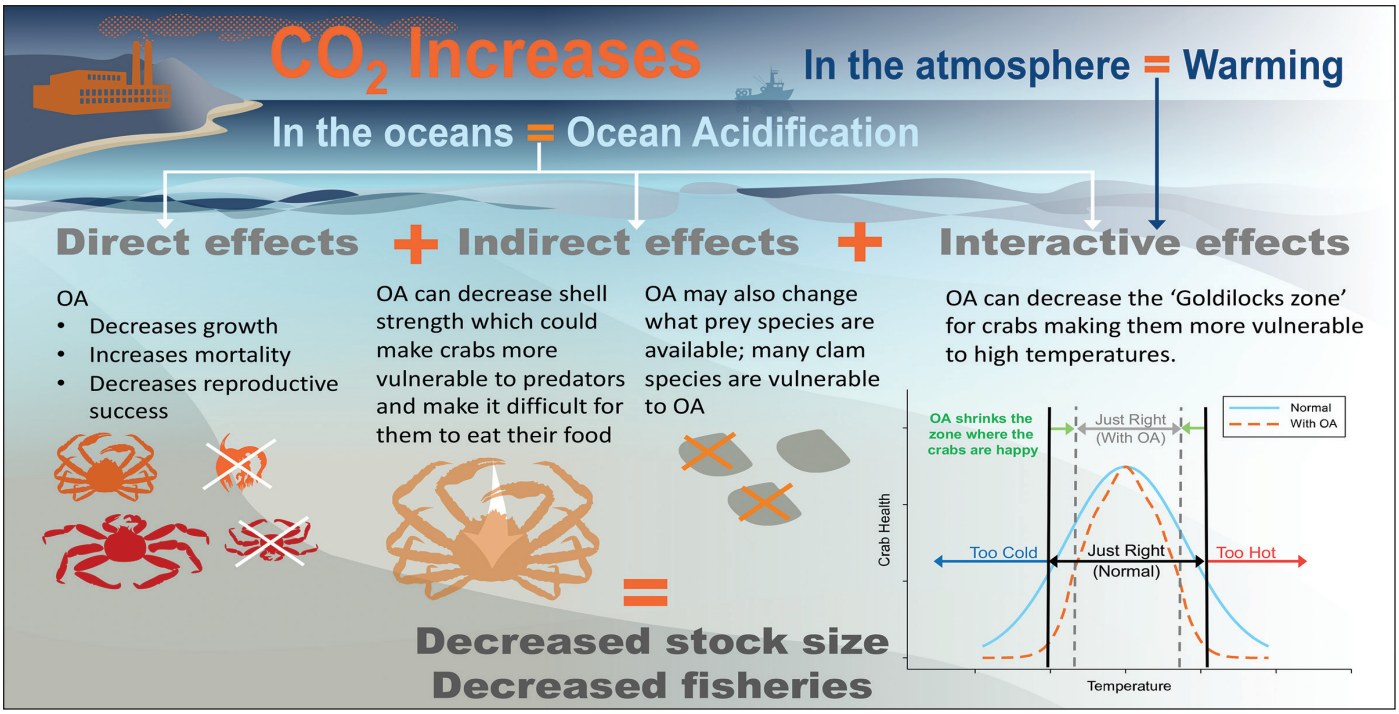
- Increased risk of predation
- Trouble consuming hard-shelled prey
- Greater risk of disease
- Reduced prey availability

Multiple stressors - high CO_2 water + increased temperature *(To date only red king crab juveniles tested)*

- A small increase in temperature may be beneficial for crabs in more acidic water
- A larger increase in temperature was much worse for crabs in more acidic water than would be expected from the response to each stressor alone

Future work:

- Experiments to understand the basis for crabs' response to increased acidity
- Testing the importance of indirect effects
- Understanding whether crab may acclimate or adapt
- Integrated models that look at the combined effects of acidification, temperature, and other climate-related stressors on survival and growth.



Fish

Research shows variation in the sensitivity of Alaska fish species to ocean acidification, ranging from no effect to significant consequences. High CO_2 (more acidic) conditions can influence several mechanisms in fish: direct effects on growth or survival in early life stages (eggs, larvae, juveniles); disruptions to behavior and sensory systems; and alterations of their prey.

Direct physiological responses to high CO_2 (more acidic water) include:

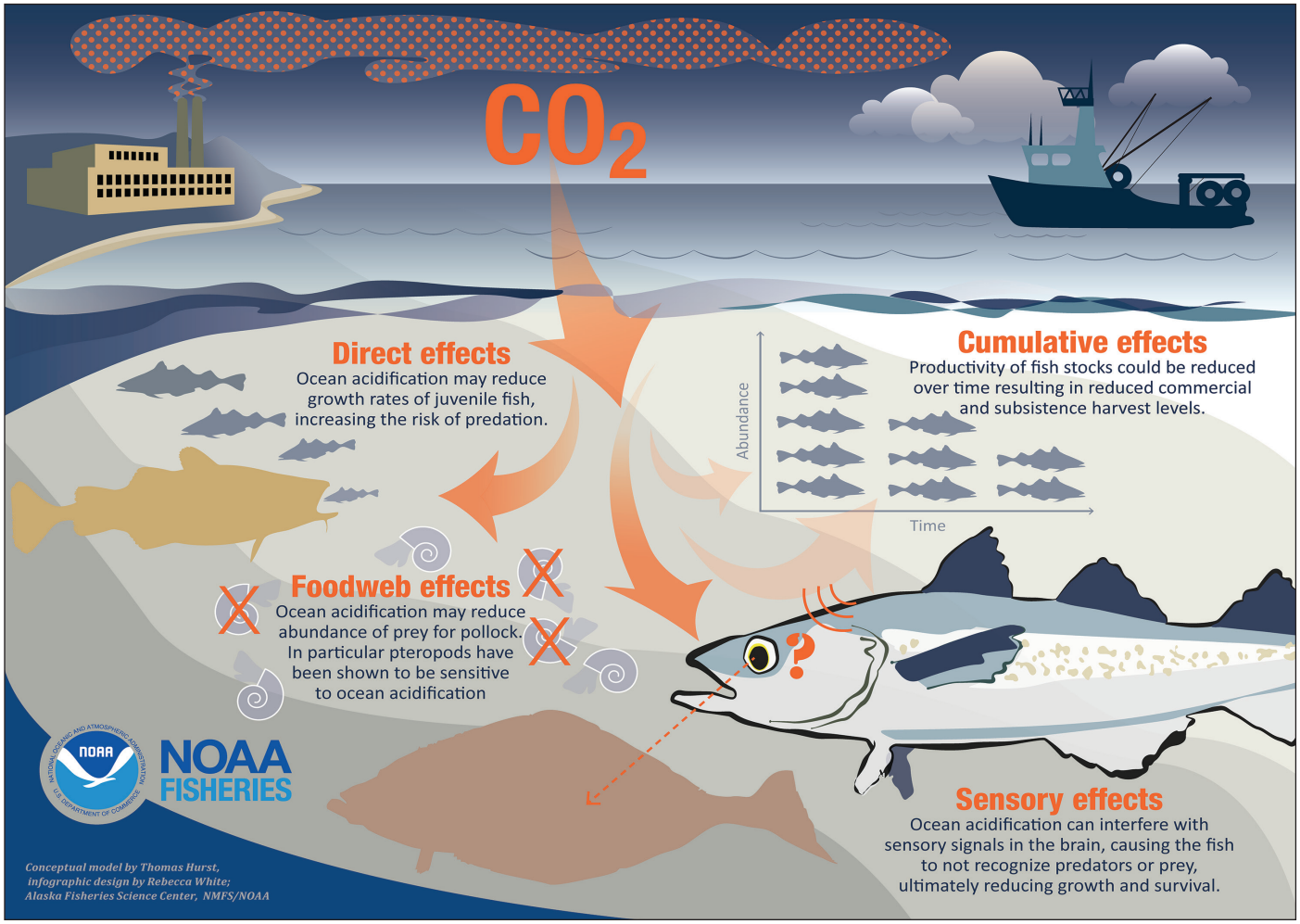
- Walleye pollock larvae and juveniles appear resilient
- Reduced growth rates in first-feeding larval Pacific cod
- Northern rock sole larvae had reduced body condition and survival
- High CO_2 did not worsen effects of low prey availability in northern rock sole
- Pacific cod larvae experienced altered behavior
- Pink and Chinook salmon experienced reduced sense of smell

Implications of ocean warming (examples):

- Steep reduction in Pacific cod in the Gulf of Alaska during recent and current ocean heat waves
- Movement of cod into new areas of the northern Bering Sea
- Changes in the timing of salmon returns and increased in-river mortality before spawning
- Few pollock and Pacific cod young of the year in Gulf of Alaska
- Zooplankton prey base dominated by small, lipid-poor copepods; low abundances of large copepods and euphausiids. Impacts to carrying capacity throughout the system

Ongoing research:

- Potential sub-lethal effects of higher acidity on walleye pollock larvae
- Acidification-induced changes in nutritional quality of prey on northern rock sole larvae
- Acidification influences on foraging and anti-predator behavior of walleye pollock
- Modeling cumulative effects of high CO_2 and temperature on Pacific cod population
- Potential economic impacts of ocean acidification on Alaska salmon fisheries



AOOS Alaska Ocean Observing System

NOAA FISHERIES

Alaska Ocean Acidification Network